



**Michigan
Technological
University**

Michigan Technological University
Digital Commons @ Michigan Tech

Department of Electrical and Computer
Engineering Annual Reports

Department of Electrical and Computer
Engineering

1-1-2007

Electrical and Computer Engineering Research Report 2007

Department of Electrical and Computer Engineering, Michigan Technological University

Follow this and additional works at: <https://digitalcommons.mtu.edu/ece-annualreports>



Part of the [Electrical and Computer Engineering Commons](#)

Recommended Citation

Department of Electrical and Computer Engineering, Michigan Technological University, "Electrical and Computer Engineering Research Report 2007" (2007). *Department of Electrical and Computer Engineering Annual Reports*. 7.

<https://digitalcommons.mtu.edu/ece-annualreports/7>

Follow this and additional works at: <https://digitalcommons.mtu.edu/ece-annualreports>



Part of the [Electrical and Computer Engineering Commons](#)

**MICHIGAN
TECHNOLOGICAL
UNIVERSITY**

ECE

**ELECTRICAL AND COMPUTER ENGINEERING
RESEARCH REPORT**



GREETINGS FROM THE NORTH COUNTRY

IT HAS BEEN ANOTHER EXCITING YEAR here at Michigan Tech. Our graduate enrollment is at an all-time high, our research expenditures continue to grow, and our students and faculty are tackling many exciting research questions.

Of particular note, Chunxiao (Tricia) Chigan received a highly coveted National Science Foundation CAREER award for her work in wireless ad hoc networks. With that award, she will look at ad hoc networks in automobiles—one of the most promising applications for several networks that she is studying.

And research involvement is growing. Undergraduate research has become an important part of the education of many of our students. One of the ways they participate is through our one-of-a-kind Enterprise program. There are twenty-five Enterprise teams on campus, and we highlight the three that make their home in the ECE department.

Last year we hired three new faculty members. Chris Middlebrook joined us in August, and his work is profiled on page eight. Wayne Weaver, who works on the power electronic interfaces of microgrids, and Shiyan Hu, who has developed new techniques to minimize defects in VLSI designs, will be joining us for the spring semester.

On a personal note, I have succeeded Tim Schulz as chair of electrical and computer engineering until we complete a national search for his successor in the department. In July, Tim was appointed dean of the College of Engineering at Michigan Tech. He was chair of the ECE department for eight years, leading us through a rapid growth in research, some of which is shown within these pages. We thank him for his efforts and look forward to working with him as he leads the college forward.

Leonard Bohmann
Interim Chair

CONTENTS

- 4 ABOUT THE DEPARTMENT
- 5 GRADUATES AND RESEARCH
- 6 NSF CAREER AWARD WINNER
- 8 NEW FACULTY SPOTLIGHT
- 9 RESEARCH PROGRAMS
- 16 ENTERPRISE TEAM UPDATES

ABOUT THE DEPARTMENT

Established in 1928, the Department of Electrical and Computer Engineering (ECE) at Michigan Tech has been supplying the world with highly skilled scientists and engineers whose credentials and innovations are unmatched. The department is a working laboratory in which students and faculty pursue and create knowledge at its cutting edge.

Our programs are suited to today's technological society. Students have flexibility as they choose how to make their mark on the world. Bachelor of Science degree programs include electrical engineering and computer engineering, as well as a photonics concentration. We offer both MS and PhD programs in electrical engineering, with concentrations in computer engineering, energy systems, information systems, and solid-state electronics.

OUR FACULTY

ECE faculty are accomplished, and their work is prominent worldwide. Several hold editorial positions with major journals, including *IEEE Transactions on Image Processing*, the *Journal of the Optical Society of America*, *Applied Optics*, the *International Journal of Modeling and Simulation*, and the *Journal of Electric Power Components and Systems*.

Many have been named fellows in international organizations, including the Association for Computing Machinery, the Institute of Electrical and Electronics Engineers, the Optical Society of America, the International Society for Optical Engineering, and the Society of Women Engineers.

TENURE-TRACK FACULTY

ASHOK K. AMBARDAR

PHD, UNIVERSITY OF WYOMING

PAUL L. BERGSTROM

PHD, UNIVERSITY OF MICHIGAN

LEONARD J. BOHMANN

PHD, UNIVERSITY OF WISCONSIN

JEFFREY B. BURL

PHD, UNIVERSITY OF CALIFORNIA, IRVINE

CHUNXIAO (TRICIA) CHIGAN

PHD, STATE UNIVERSITY OF NEW YORK—STONY BROOK

ASHOK K. GOEL

PHD, JOHNS HOPKINS UNIVERSITY

SHIYAN HU

PHD, TEXAS A&M UNIVERSITY

ROGER M. KIECKHAFFER

PHD, CORNELL UNIVERSITY

ANAND K. KULKARNI

PHD, UNIVERSITY OF NEBRASKA

MELISSA G. MEYER

PHD, UNIVERSITY OF WASHINGTON

CHRISTOPHER T. MIDDLEBROOK

PHD, UNIVERSITY OF CENTRAL FLORIDA

PIYUSH MISHRA

PHD, POLYTECHNIC UNIVERSITY

BRUCE A. MORK

PHD, NORTH DAKOTA STATE UNIVERSITY

WARREN F. PERGER

PHD, COLORADO STATE UNIVERSITY

MICHAEL C. ROGGMANN

PHD, AIR FORCE INSTITUTE OF TECHNOLOGY

TIMOTHY J. SCHULZ

PHD, WASHINGTON UNIVERSITY

MARTHA E. SLOAN

PHD, STANFORD UNIVERSITY

JINDONG TAN

PHD, MICHIGAN STATE UNIVERSITY

ZHI (GERRY) TIAN

PHD, GEORGE MASON UNIVERSITY

WAYNE W. WEAVER

PHD, UNIVERSITY OF ILLINOIS

DENNIS O. WIITANEN

PHD, UNIVERSITY OF MISSOURI—ROLLA

SEYED (REZA) ZEKAVAT

PHD, COLORADO STATE UNIVERSITY

ZHIJUN (ZAK) ZHAO

PHD, UNIVERSITY OF ILLINOIS

RECENT PHD GRADUATES

JASON ARBUCKLE

Indicated mean effective pressure estimation with applications to adaptive calibration

BAOYONG LIU

Optimal beam forming for laser beam propagation through random media

PAUL WEBER

Dynamic reduction algorithms for fault tolerant convergent voting with hybrid faults

MELISSA TROMBLEY

Localized annealing of polysilicon microstructures by inductively heated ferromagnetic films

ALEKSANDER SERGEYEV

Bootstrap beacon creation for overcoming the effects of beacon anisoplanatism in laser beam projection system

JUN SHAO

Reducing main memory access latency through SDRAM address mapping techniques and access reordering mechanisms

LEE PAULSEN

A study of and design procedure for dual circularly polarized waveguide slot arrays

YANCHAI ZHANG

Compensation of laser beam projection through strong turbulence with multi-mirror adaptive optics system

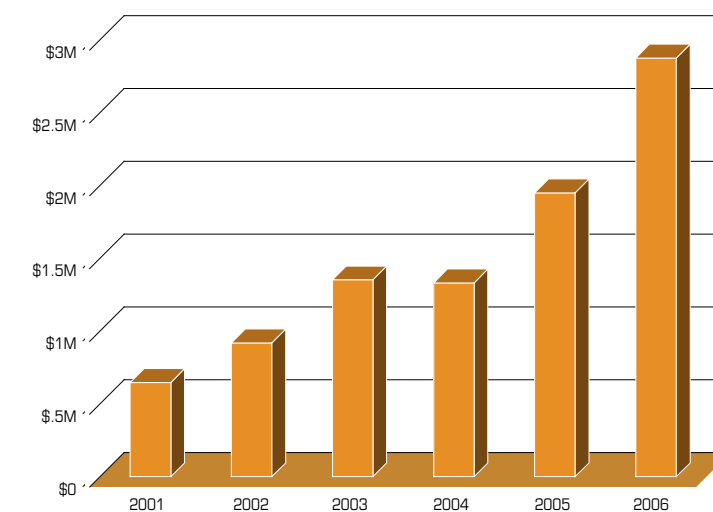
JIN ZHENG-WALNER

Porous silicon technology for integrated microsystems

LIN WU

Timing synchronization and receiver design for Ultra-Wireband communications

RESEARCH EXPENDITURES



RESEARCH

Important research programs continue in the areas of sensing and imaging, wireless communications and networks, electric power and energy, and solid-state electronics.

The department is enjoying unprecedented growth in research and graduate education. In the past six years, PhD enrollment has tripled, and research expenditures have quadrupled. Much of this growth has taken place within two major research centers. The Center for Integrated Systems in Sensing, Imaging, and Communications (CISSIC) integrates physical models, device technologies, and signal-processing theory. The Power and Energy Research Center (PERC) tackles new challenges in power engineering. Those include alternate and renewable energy, new energy technologies, and restructuring and deregulation of the utility industry.

ECE faculty members are also engaged in interdisciplinary research institutes and centers on campus and nationwide. Faculty serve in leading roles with the Multi Scale Technologies Institute, the Remote Sensing Institute, the Keweenaw Research Center, the Engineering Research Center for Wireless Integrated Microsystems, and others at Michigan Tech and across the US.

Department research is funded by multiple agencies and corporations, including the National Science Foundation, the US Army and Air Force, Intelligent Automation, SINTEF Energy Research, Xcel Energy, Eaton, the Michigan Department of Transportation, International Transmission, American Electric Power, Consumers Energy, and more.

INTELLIGENT TRANSPORTATION

VEHICLES ARE ABOUT TO GET A LOT SMARTER—AND SAFER—WITH HELP FROM TRICIA CHIGAN

VEHICULAR COLLISIONS ARE A LEADING CAUSE of death and injury in many countries around the world. On an average day in the United States, auto accidents kill 116 and injure over 7,900, making it the leading cause of death for people under age thirty-five. The US spends more health-care dollars treating crash victims than any other cause of illness or injury. With an annual economic impact of close to \$200 billion, the US Department of Transportation has declared the reduction of vehicular fatalities its top priority.



▲ Tricia Chigan

"Vehicular ad hoc network communications could greatly enhance traffic safety and traffic operation," says Chunxiao (Tricia) Chigan, an assistant professor of electrical and computer engineering at Michigan Tech.

Chigan is studying a new form of wireless technology, the vehicular ad hoc network, or VANET for short. VANET provides inter-vehicle communications capability and more.

"VANET has genuine life-saving potential," she notes. "In the coming years as this new technology is adopted around

the world, I hope to see a substantial reduction in the rate of automobile accident-related death."

Chigan is a 2007 National Science Foundation CAREER Award winner. Her CAREER project addresses major challenges in VANET-related access technology, dynamic power control, multi-hop communication, and security and privacy.

The success of Chigan's project will open the door for many new VANET applications in the areas of traffic safety, cooperative traffic operation, vehicle probe data acquisition, and information sharing.

VANET provides its users with "the ability to form a communication system anytime, anywhere, dynamically, without pre-established communication infrastructures such as the optical network and the cellular network," she explains. It can provide real-time collision avoidance via warning technology to improve driving safety. It has the potential to improve traffic conditions by making 'cooperative driving' possible. And it can potentially notify drivers of road hazards, road blocks, traffic conditions, auto accidents and rush-hour re-routing.

"The highway horrors experienced during the evacuation of Hurricane Rita demonstrated the strong need for dynamic traffic planning in emergency situations," adds Chigan. "And there are several other potential applications. For instance, once equipped with the appropriate sensors, VANET can be used for data acquisition, such as collecting and processing traffic data to calibrate national bridge live-load models."

Another bonus: cooperative driving could reduce fuel usage. "Smarter, VANET-supported driving could mean less carbon in the atmosphere—reducing air pollution and helping to preserve the environment."

According to Chigan, wireless mesh networking has drawn extensive attention as an emerging wireless paradigm to resolve the limitations and significantly improve the per-



formance of ad hoc networks, wireless local area networks (WLANs), wireless personal area networks (WPANs), and wireless metropolitan area networks (WMANs).

"Included as one special element of an ad hoc network, VANET can serve as a fully opportunistic network extension in the wireless mesh network paradigm," says Chigan. "This has great potential for emergency crews, who can then quickly establish a network when working at a disaster site."



CHUNXIAO (TRICIA) CHIGAN is an assistant professor of electrical and computer engineering. She is a recipient of the National Science Foundation CAREER Award (2007).

Prior to joining the faculty at Michigan Tech, Chigan was a visiting scholar with High Performance Communications Systems at Bell Labs, Lucent Technologies (Holmdel, New Jersey).

She received MS and PhD degrees in electrical engineering from the State University of New York, Stony Brook, in 2000 and 2002 respectively.

Research interests include:

- vehicular ad hoc networks
- wireless ad hoc and sensor networks
- wireless network security
- adaptive network protocol design for cognitive radio networks
- dependable computing and communication systems
- network resource allocation and management

SEEING IN THE DARK

A FRESH FOCUS ON INFRARED SIGNALS

RODS AND CONES WITHIN THE HUMAN EYE are only responsive to the visible portion of the electromagnetic spectrum (400-700nm). In a situation where there is no visible light source available, those rods and cones cannot respond, and the viewer is effectively blind.

Using detectors that are sensitive to the infrared (8-12 microns) portion of the electromagnetic spectrum allows an image to be created in the same way a digital camera makes an image, allowing the viewer to "see" in the dark.

"One way this sensing can be done is with the use of very tiny nanowire antennas which respond to infrared radiation," notes Christopher Middlebrook, an assistant professor of electrical and computer engineering at Michigan Tech.

Middlebrook is working on phased infrared "nanowire" technology that allows for a much more compact and lightweight imaging device without the use of optical components. Typical infrared detection mechanisms require costly and bulky optical components in order to deliver the infrared radiation to the detector.

Phased-array antennas are commonplace in the radio-frequency portion of the electromagnetic spectrum. "Taken one step further, exploitation of phasing effects between multiple antennas opens up a wide range of applications, including synthetic-aperture radar, beam forming, and beam scanning," he says. "It's useful in just about any remote sensing type of situation, such as unmanned aerial vehicles, planes, and satellites."

Middlebrook recently earned his PhD in optics at the University of Central Florida. His professional experience started with a stint in the US Navy as an aviation electronics mate stationed in Norfolk, Virginia, with several Mediterranean deployments. He then spent three years working as an electrician for K&F Manufacturing in Granger, Indiana, before coming to Michigan Tech to study electrical engineering as an undergraduate.

Next, Middlebrook went to work for the electro-optics department at NAVSEA in Crane, Indiana. At NAVSEA, he

generated research proposals and grants as a co-founder of a start-up science and technology team charged with increasing R&D workload. He also completed an MS in applied optics at the Rose Hulman Institute of Technology in nearby Terre Haute.

His next stop: Orlando, Florida, where he completed his PhD last June. While there, Middlebrook became involved



▲ Christopher Middlebrook

with a joint research project with two Michigan Tech photonics experts: ECE Professor Mike Roggemann and Nik Subotic, director of the Michigan Tech Research Institute (MTRI).

"Through this venture—an application of gold nanowire antennas—I learned about the photonics concentration within the ECE department and their desire to develop more research areas in the field." Now, newly arrived at Michigan Tech, Middlebrook plans to build upon his infrared antenna work, focusing on the routing and transmission of infrared signals.

So what is it like coming back to Michigan Tech after all these years?

"It's exciting to be a part of Michigan Tech again, with the direction it is heading in terms of growth and research. I enjoy the mix of electrical engineering and optics and couldn't think of a better place to be."

THE AUGER NORTH PROJECT

STUDYING THE UNIVERSE'S HIGHEST ENERGY PARTICLES

COSMIC RAYS ARE CHARGED SUBATOMIC PARTICLES that fly through space and constantly shower the Earth. Occasionally a cosmic ray with an energy of 10^{20} electron volts (eV) or higher enters the atmosphere, packing an energetic punch 100 million times greater than can be created in the world's most powerful particle accelerator.

These ultra-high-energy cosmic rays have been one of the enduring mysteries of science. Their origin and nature remain unknown seventy years after their discovery—until now, that is.

The Pierre Auger Observatory, named for the French physicist who first identified cosmic rays in 1938, has recorded almost a million cosmic-ray showers since its particle detectors and twenty-four specially designed telescopes started collecting data in 2004.



Three years of data collection and analysis is helping to bring the Pierre Auger Collaboration closer to understanding the mystery of the origin of the highest-energy cosmic rays.

Auger researchers have identified Active Galactic Nuclei (AGNs)—containing massive black holes—as the most likely source of the highest-energy cosmic rays.



▲ The Los Leones fluorescence detector together with its closest surface detector tank

It is, however, the twenty-seven highest energy particles that are the most striking. Researchers found that most of those twenty-seven came from the locations of the nearest AGNs, within a few hundred million light years of Earth.

Studying these super-energetic cosmic rays would be easier if there were more of them. They connect with the Earth at the estimated rate of just one per square kilometer per century.

To catch a glimpse of these rare subatomic particles and their somewhat more common brethren, 10^{19} eV cosmic rays, more than 300 scientists from seventeen countries

have been building the southern site of the Pierre Auger Observatory. That detector, which covers three thousand square kilometers east of the Andes, is now approaching completion near the town of Malargue, Mendoza Province in western Argentina.

On the beautiful plains of southeast Colorado, a new window on the universe is taking shape. There, the Pierre Auger Cosmic Ray Observatory Northern Site will be built. That facility will be able to detect air showers within the northern hemisphere, so scientists can study cosmic rays hitting the Earth from all directions.

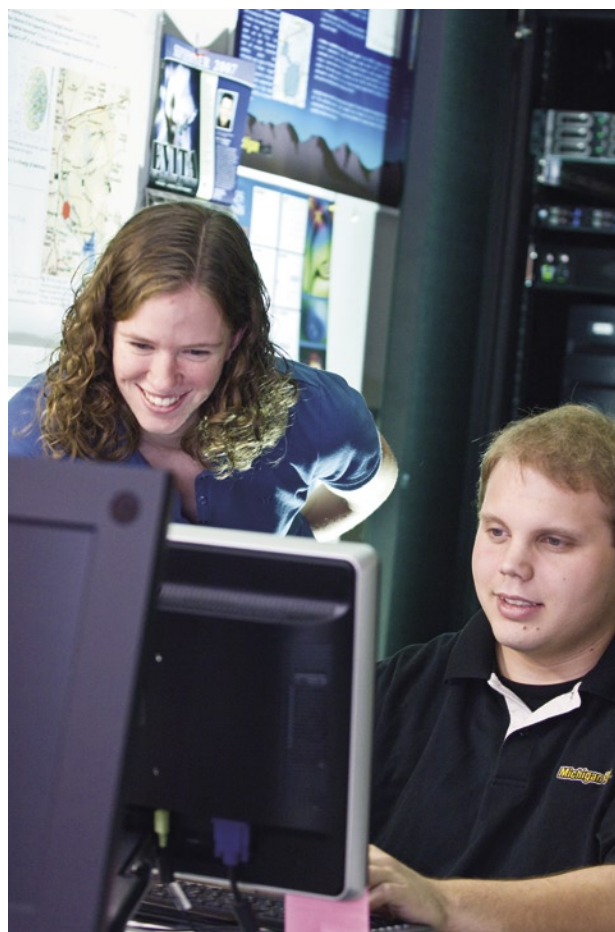
Electrical and Computer Engineering Associate Professor Roger Kieckhafer is participating in the Auger North project, which is managed by the Department of Energy's Fermi National Accelerator Laboratory. He joins Michigan Tech Professor David Nitz and Associate Professor Brian Fick, both in physics, who have been on the Auger Observatory project since its inception back in 1992.

Kieckhafer has been working closely with two ECE undergraduate student researchers, James Hollenbeck and Amy Palmgren. Together, they are members of the Auger North Surface Detector Communications team, along with Michigan Tech ECE assistant professors Tricia Chigan, Jindong Tan, and Piyush Mishra.

The Auger North installation will contain over four-thousand particle sensors called surface detectors (SDs), arrayed over a 48-by-84 square mile grid near the city of Lamar, in southeastern Colorado. The Michigan Tech ECE Team has created a new wireless communication protocol to transfer data quickly and reliably from all four-thousand SDs to the observatory campus for analysis. They are currently working to specify, write, and verify the software to redundantly route the data from each detector to the campus, and hope to install a twenty-node prototype research and development array in Colorado this summer.

AMY PALMGREN

I first got involved in the project last spring semester through my Enterprise team, Wireless Communications Enterprise (WCE). We worked with Dr. Kieckhafer and Dr. Nitz to verify and demonstrate the new Wireless Infrastructure for High Assurance Real-Time (WIHART) protocol [1]. The



▲ Amy Palmgren and James Hollenbeck

protocol allows surface detectors (SDs) to forward information down a chain of SDs as opposed to each SD sending its data directly to a single, central antenna. This allows for data to arrive at the control station in a steady, predictable stream and significantly shortens the distance a single transmission travels in the air.

WCE wrote software for Tmote Sky transmitters, which were used to simulate a chain of surface detectors on a smaller scale. Our group was able to successfully implement the protocol and demonstrate it on the eighth floor of the EERC building. This even involved transmitting messages around a corner, known as a Mobius fold.

The success of our research is part of the reason why Michigan Tech was given the task of implementing the real software for the Auger North Observatory. As a result, I was offered the chance to work on the software for the network.

It was very rewarding to know that the work I put in last spring was an important part of the observatory's choice to use the WIHART protocol.

The best part is to be able to see that my research truly has an impact. I cannot wait to go to Colorado to install the prototype system—and know that the software I helped to write is allowing the network to communicate, and thus helping physicists to study cosmic rays.

JAMES HOLLENBECK

I never knew that this project existed until May 2007, when I got an email about a program called SURF (Summer Undergraduate Research Fellowship), which involved working with a mentor over the summer to take part in a research project. Roger Kieckhafer was actually the last professor that I approached, and he agreed with this project in mind.

Even before the SURF research began, Roger and Dave Nitz gained funding for yet another position: they needed help writing the code that the nodes would need to complete message transfers. Once the summer was complete, Roger offered me that position, along with Amy, and we began specifying and verifying the protocols for message transferring.

The main phase of the project involves us spending from now until summer getting the communication protocols specified and verified, so they may be implemented within the small test array, and hopefully allow for a "go" on the rest of the project.

The experience so far has been incredible. I am being exposed to a good chunk of my degree requirements before learning about them in any of my classes. As a result, the research is demanding for me. Unlike Amy, I have almost no background in what I am doing, so I have to learn everything as I go, and as fast as possible. There have been no daunting moments, however, just very challenging ones.

Because of this project, I am getting to be part of incredible real-life applications of my degree. I am gaining better thinking and writing skills and experiencing the ups and downs of field work and research. There is never a lack of work, and every day is a little different from the last.

THE PIERRE AUGER OBSERVATORY

WHAT ARE COSMIC RAYS?

Cosmic rays are very energetic charged particles that continually bombard the Earth. These particles are usually protons but can also be larger nuclei. When such a particle strikes the Earth's atmosphere, it creates a shower of lower energy secondary particles, and these are observed to reach the ground. In fact, about a hundred of these secondary particles pass through our bodies every second. Exposure to cosmic rays is even greater at high altitudes.

WHERE DO COSMIC RAYS COME FROM?

The Active Galactic Nuclei (AGN) recently identified by the Auger Collaboration as the source of the highest-energy cosmic rays are thought to be powered by super-massive black holes that are devouring large amounts of gas, dust and other matter from their host galaxies and spewing out particles and energy.

Most galaxies have black holes at their center, but only a small fraction have an AGN. The black hole at the center of our galaxy, the Milky Way, is not an AGN.

The findings of the Auger Collaboration are reported in the Nov. 9, 2007, issue of the journal *Science*.

Text excerpted by permission from The Pierre Auger Northern Observatory web site, www.augernorth.org

Reference List

[1] R.M. Kieckhafer, P. Mishra, J. Tan, C. Chigan, "A New Paradigm for Reliable Hard-Real-Time WSNs", IEEE Real-Time Systems Symposium (RTSS-06), Work in Progress Session, Dec 2006.

HUMANS + ROBOTS

ENHANCING THE CAPABILITY OF BOTH

THE DEPARTMENT OF ELECTRICAL AND COMPUTER Engineering and five other departments recently acquired funding from the US Department of Defense to establish a Human Robot Interaction (HRI) laboratory at Michigan Tech. Their goal: To integrate the intelligence of humans with the power of robots.

Creation of the new HRI lab is now underway. The first shipment of sixteen robots arrived in early November.

The lab will contain both indoor and outdoor facilities, forming one integrated system of large-scale, interdisciplinary HRI studies, including offensive and defensive military simulations.

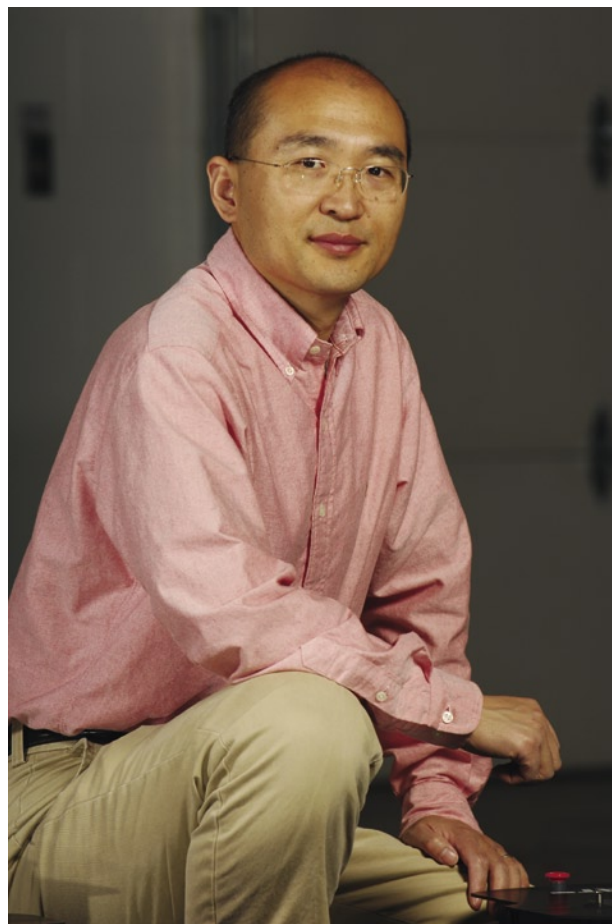
Seven Michigan Tech professors, including Electrical and Computer Engineering Assistant Professor Jindong Tan, will conduct HRI research in the coming months.

The HRI lab will enable researchers and students to work collaboratively on critical technologies, such as remote navigation and control of robots, remote robotic data collection, remote sensor networks, and automated reasoning and plan execution. They will also use biosensors to gain an understanding of critical human decision making during human-robot teaming.

Just how well do humans and robots interact? "Not quite as well as they could," says Tan. "But the future includes increasing numbers of robots working in collaboration with humans, something that is also a critical component of future military operations."

In addition, wireless sensor networks embedded in our surroundings are poised to become an integral part of domestic and military environments, as well as our everyday life. "In a net-centric world that involves intelligent sensors, robots, and distributed information management systems, humans are no longer simply users of these systems," notes Tan. "Humans are becoming an essential system component."

Yet a key feature of human-robot teams, human cognitive ability, is difficult to automate.



▲ Jindong Tan

"On the one hand, much more information is available for human decision makers in a sensor network environment, greatly increasing the complexity. On the other, the addition of 'human components' with superior intelligence and cognitive power can significantly improve overall performance, if integrated into the system. The interaction between a wireless sensor network and a multi-robot system actually enhances the capability of both."

Compared to a multi-robot team, a robot sensor network, or RSN, provides situation awareness in a broader area. "Robot-embedded sensors enable a human to 'see'

and act in visually and physically obstructed environment," notes Tan.

"Add humans to the mix and you've got a human, robot and sensor network (HRSN) system with its own research challenges. Integrating humans and RSNs as a symbiotic team remains a challenge."

Or rather, two challenges: How does a human interpret and understand the sensor network data? And, how does the sensor network react to humans and interpret human intentions?

Tan plans to address the first challenge via information exploitation algorithms. Instead of delivering a large volume of unprocessed sensing data, aggregated sensing data coupled with in-network processing can be provided to human users.

In the second case, Tan and his team plan to develop wireless wearable motion sensors for human users, which can function as interaction devices. That way, rather than interacting with abstract objects in virtual environments, humans can interact with sensors and robots in real environments using gesture control devices.

The indoor portion of the new HRI lab will provide just the right environment for testing. It will feature advanced virtual reality equipment for visualization and remote sensing, along with a wireless biosensors network. The outside field will offer a stationary sensor network, unmanned ground and aerial vehicles, and wireless biosensor equipment for human interaction. It will be managed in cooperation with Michigan Technological University's Keweenaw Research Center, which has an extensive record of testing military vehicles.

THE NEW HUMAN ROBOT INTERACTION LAB is a collaborative endeavor. The initial phase will revolve around the research interests of seven faculty members: William Helton III (psychology), Jindong Tan (electrical & computer engineering), Amlan Mukherjee (civil and environmental engineering), Yue Li (civil and environmental engineering), Robert Pastel (computer science), Nilufer Onder (computer science), and Jason Carter (exercise science).

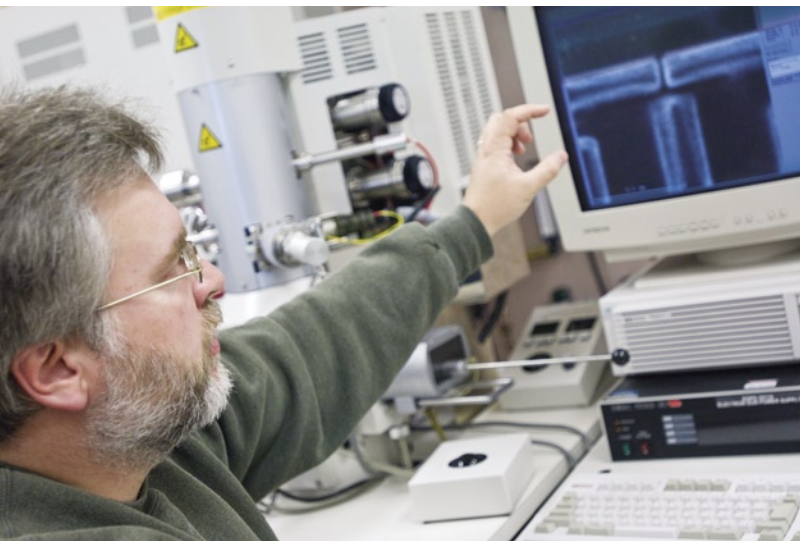


▲ A few of the HRI lab's sixteen new robots.

SINGLE ELECTRON TRANSISTORS

Q&A WITH PAUL BERGSTROM

THE CAPABILITY OF DIGITAL ELECTRONIC DEVICES will increase significantly in the coming years, thanks to research performed by Electrical and Computer Engineering Professor Paul Bergstrom.



▲ Paul Bergstrom

With funding from the Microsystems Technology Office of the Defense Advanced Research Projects Agency and the Army Research Lab, Bergstrom and his team have successfully manufactured a single electron transistor (SET) that works at room temperature—something only one other group in the US and only a few others worldwide have achieved.

In the past, SETs have operated only at temperatures colder than liquid nitrogen.

A discovery with great potential, room-temperature SETs could open up whole new aspects of the electronics industry.

Bergstrom and his team found success by fabricating SETs using tungsten nanoislands engineered with a focused ion-beam etching tool. The technique is able to put each particle exactly where it should be.

Q: What sort of devices are candidates for the new SET technology? Cell phones are one example, correct?

A: Yes—cell phones, and any other application in which a very high density of embedded memory is desirable. Alternatively, any application in which more integrated functionality is desirable than is currently possible could benefit from the use of single electron transistors. That includes all the current multi-core processors which rely on lots of embedded memory—and millions of logic gates.

What if we could both improve aspects of each core's performance and also integrate a much higher level of embedded memory on chip? Well, we can do that now—and it's the key to continuing up the performance curve.

Q: When you talk about energy savings with SETs, what do you mean?

A: The big killer of microelectronics (aka microprocessors, and everything that powers our electronic age) is heat. Modern field effect transistor technologies waste a large part of their operating power through leakage current. The wasted power is converted directly into heat, which makes the devices leak more current, which translates into more heat, and so on.

Moving to nanoscaled electronic devices such as SETs that rely on quantum behavior will allow us to eliminate leakage current in foundational devices, which are utilized in virtually any nanoscaled electronic platform you choose to discuss.

Q: Are there other benefits?

A: More embedded functionality means more ability for the device to do what you want it to do. It may require overall less power, which would mean fewer batteries thrown out. It could result in lower heat generation which would make laptops more comfortable to use for hours on end

(on your lap—following the name convention).

It would also allow technology its continued migration toward high levels of integration (from hundreds of millions of transistors to hundreds of billions of transistors ultimately) so that the cost per device will continue to drop at its historical rate, or even faster.

There may be other functionality benefits. Current microelectronics utilize two logical states, ON and OFF, or binary logic. SETs are devices that can be designed to function at higher orders of logic, utilizing threshold levels beyond the two-state current system. This may allow more functionality in a smaller space, since fewer devices would be needed to represent a large number.

For instance, 2^{64} is a large number, but you don't need 64 unique data paths if each device can represent four or eight values instead of two. In fact, if you could represent four unique levels (0, 1, 2, and 3) you would need half as many devices overall to represent the number. Eight values (0 through 7) would be a reduction to roughly one-third the number of devices overall.

This would require a computational paradigm shift for computer science, but in its simplest sense, SETs with multi-level logic capabilities would allow two to three times the functionality in the same number of devices.

Q: Are other experts around the world attempting to develop SETs that operate at room temperature? Are you collaborating?

A: There are others in the world working on SETs, but few in the US. Much of the SET work is taking place in Japan and Korea. We have been recently trying to build linkages with theorists at Arizona State University, Purdue University and in Korea—a particularly potent competitor.

Q: What are your next steps?

A: Our goal is to demonstrate how SET devices can be fabricated in an industrially relevant method that can be integrated with current CMOS technologies. We are also working toward more fully understanding the physics behind the device's behavior and building a model structure that can be utilized by designers when considering how to design circuits and systems with SETs.

Q: How soon might we see this technology in our everyday lives, and in what form?

A: Best case, we could transfer this to industry in the next two or three years and see it in products in the next seven. Practically speaking, it may show up in a decade.

Q: Would you call this a major breakthrough in the world of nanotechnology?

A: I hate to use the word breakthrough. I think demonstrating room temperature operation is a significant step toward making this technology practical for real-world applications.

The effort is expanding at Michigan Tech and going beyond the SET devices as well. We hope to find ways to create devices ultimately that will not transfer current when they do logic. That is the 'holy grail' for nanoelectronics right now. Make a device that does logic and doesn't require charge transfer. We are taking that challenge seriously.



▲ Several of Bergstrom's former graduate students are now directly working on next generation technologies for industry.



BLUE MARBLE ENTERPRISE

BLUE MARBLE IS AN ENERGETIC GROUP of undergraduates who have formed a virtual company focused on securing the future through thoughtful use of technology.

Those who join the enterprise are exposed to a plethora of engineering projects and are able to explore and pursue their own ideas, as well as get a taste for working with industry.

In the past year, there have been team projects dealing with contamination detection within public water systems, design and development of wireless parking assistance systems, use of wireless technologies for outdoor recre-



▲ Blue Marble students designed and constructed a residential wind turbine which sits on the roof of the EERC building and powers devices in their lab.

ational enhancement, emergency traffic safety systems, and 360-degree real time video technologies. Another project involves engineering a portable, renewable energy center which will tour the US to educate the public.

One Blue Marble team recently delivered on a project with General Dynamics, providing research aimed to lessen the effects of motion sickness on military personnel who,

upon exit of a vehicle, must be alert and prepared for any environment.

Yet another project delivered in the past year was sponsored by the Michigan Department of Transportation (MDOT). The team designed a vehicular mounting system and associated electronic and software systems to provide MDOT with a means of accomplishing their geodetic tasks. These new systems allow MDOT to create a 3-D map of the road networks at high rates of speed with precision (mm to cm range). Such a product is highly useful for MDOT, as they must keep track of surface conditions and long-term settling or heaving of road beds. It also greatly reduces the man-hours associated with collecting such data, resulting in lower expenses for the State of Michigan.

In light of the world's dwindling supply of energy reserves, Blue Marble has set out to secure the future of energy through renewable sources. One team has successfully designed and constructed its own residential wind turbine, which is currently located on the roof of the EERC building. It has the ability to power devices within the Blue Marble lab, as well as promote the exploration of private/residential renewable energy sources.

Other energy-related projects include the Wearable Power Competition sponsored by the US Department of Defense. The idea is to design the lightest portable power supply which could be carried by military personnel to provide 20 Watts of power for the duration of a 96-hour mission.

Other current projects involve emergency traffic safety systems, large-scale inventory and location-tracking systems, innovative methods of providing medical history in more efficient ways, and remotely operated and robotic video systems for military use.

Blue Marble is also fostering the development of a brand-new enterprise—the Automotive Computing Enterprise, which will develop automotive software and hardware for aftermarket venues and manufacturers.

Blue Marble received awards this past year from the Michigan Homeland Security Consortium and was named "Best Invited Team" at the Illinois Institute of Technology's 2007 Interprofessional Projects Program (IPRO) Day Conference, held in Chicago, Illinois.



WIRELESS COMMUNICATION ENTERPRISE (WCE)

WCE CREATES WIRELESS, OPTICAL, AND BIOMEDICAL technology solutions for real people. The enterprise operates as a virtual company, with students holding leadership positions at the project and executive level. WCE is large and has as many as twelve different teams working during a semester.

Recently a team worked with biomedical company Boston Scientific to develop applications for PDAs and cell phones. WCE delivered a solution to Boston Scientific that transferred medical data to and from these handheld devices using the Bluetooth communication protocol.

There has been a current and growing focus on renewable energy worldwide, and WCE represents part of this trend. Recently, the enterprise started a research project on



▲ WCE works like a think tank for companies looking to push their product lines to a higher level.

how to harness renewable energy for use at the University and how to utilize renewable energy on a smaller scale for home use.

WCE also runs several internal (proprietary) projects each semester, most of which start with ideas brainstormed from current members. These projects range from biosensors, to remote controls, to robots. WCE continues to grow every semester, adding new projects and industry contacts.

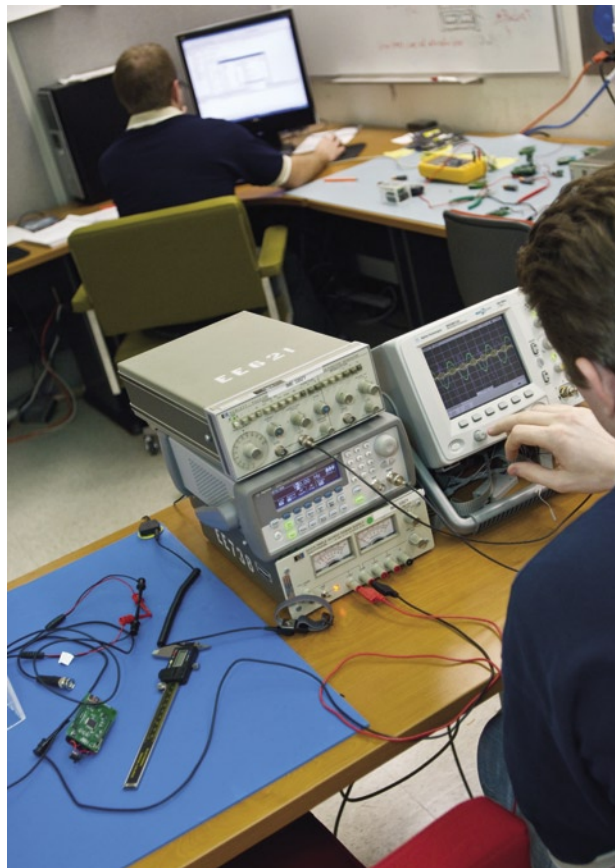




INTEGRATED MICROSYSTEMS ENTERPRISE (IME)

IME CURRENTLY WORKS ON A WIDE variety of projects, but their best-known project is the Data Acquisition Cube (DAC), a learning tool for middle- and high-school science students.

With the DAC, students can make up their own science experiments and get quantitative results instantly. The team believes that in today's fast-paced world, students should have the technology to learn the way that industry does,



▲ The DAC features an interchangeable sensor card and software suite to display, record, and analyze classroom experiments.

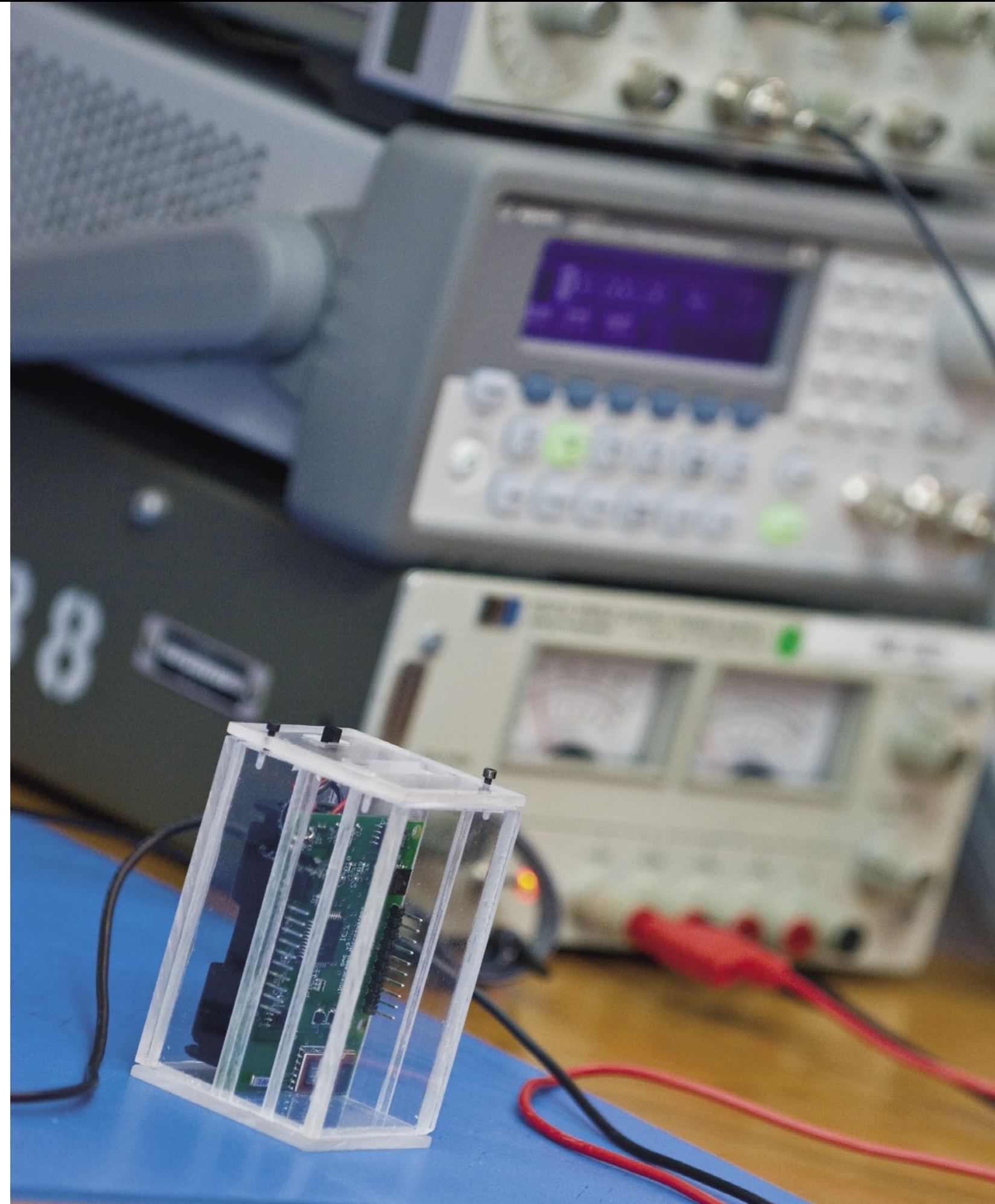


▲ The IME motto: Real goals. Real innovation. A real way.

with its ability to monitor and control products. Using the DAC device, a student can monitor the speed and acceleration of a thrown football or the height of a model rocket in the air. The only limit to the DAC's application is the user's creativity.

The IME team is developing many other devices, as well. They are currently engineering a sensor the size of a quarter to be placed into highways as construction crews lay down new road. The team is working with a local hospital to develop a very tiny sensor for doctors and is working on creating new wireless technologies that could one day change the way you turn off the lights.

Students in IME have the ability to engineer just about anything they can imagine. Their mission is to allow undergraduate engineers to participate in meaningful technological research and development, enabling them to get the kind of hands-on experience that jump-starts their careers. IME takes pride in working with local business, high schools, and other on-campus student organizations to develop innovative and unique products.



MichiganTech

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Michigan Technological University
121 Electrical Energy Resources Center
1400 Townsend Drive
Houghton, Michigan 49931

T: 906-487-2550
F: 906-487-2949
E: ecceinfo@mtu.edu
www.ece.mtu.edu

Michigan Technological University is an equal opportunity educational institution/equal opportunity employer. Since 1885, we have offered educational excellence in beautiful Upper Michigan. Our students create the future in arts, humanities, and social sciences; business and economics; computing; engineering; forestry and environmental science; the sciences; and technology.

